Interrupted Cognition and Design for Non-Disruptiveness: The Skilled Memory Approach

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ABSTRACT
Interruptions have gained in importance as a topic in current HCI research. Through a series of experiments, we take a step toward analyzing the active role of human memory in controlling interruptions. The results of these experiments lead us to propose a novel approach, the skilled memory approach, to how UIs can support memory in skilled management of and recovery from interruptions.

Categories & Subject Descriptors: H5.2 User Interfaces

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INTRODUCTION
An *interruption* is a temporary cognitive switch-away that breaks the fluent processing of a *main task*. In HCI, interruptions are known to cause disruption, negative emotions, and stress, particularly if they are uncontrollable, unpredictable, effortful, or of no significance to the user.

Our starting point is that interruptions are considered negative when they are felt to be waste of time and/or re-orienting to the main task requires effort. Hence, we focus on the role of memory in managing interruptions in a future-oriented manner. Our specific objective is to understand 1) *multitasking control mechanisms* that enable timely transition to the interrupting task, and 2) *the anticipation of re-orientation* in the *skilled encoding of the main task*. This approach broadens the existing literature on how different qualities of interruption timing and representation affect performance in the main task.

INTERRUPTED COGNITION: STUDIES AND FINDINGS
Our experimental methods include observational studies, as well as controlled laboratory and mobile experiments. Application domains include PC-based and mobile browsing, reading, communications, and ubiquitous multimedia.

1 Memory and the control of multiple tasks

Cognitive resources and the management of multiple tasks

In mobility, interaction tasks compete for the same resources as mobility tasks. Our *Resource Competition Framework* (RCF) suggests how psychosocial tasks typical of mobile use contexts compete for cognitive resources and how this competition leads to resources being diverted from interaction and to the eventual breakdown of fluent interaction. Predictions were tested in a controlled mobile "quasi-experiment" in which participants' attention was monitored while they performed web search tasks on a mobile phone in nine real urban mobile situations. The data convey the impulsive, fragmented, and drastically short-term nature of attention in mobile interaction. Over eight-fold differences in several micro-level measures of attentional resources were recorded in these nine situations, with breakdowns ranging in length from over 16 seconds in laboratory conditions to bursts of just a few seconds in extreme mobile situations. We also made tentative observations of compensatory strategies*:* withdrawing resources from tasks of secondary importance, calibrating perceptual sampling, and resisting task-switches just before task-finalization [6]. Interestingly, in a field study of a mobile image-sharing application, we observed strategies in which use was postponed when the resources demanded by image-sharing were perceived as too high in respect to the main task [1].

Conative structures and task-switching decisions

Our work indicates that a decision to switch tasks emerges from delicate balancing between hierarchically organized preferential structures and the demands of the task at hand. Therefore, task-switching depends not only on social and cognitive factors, but also on *conative* (motivational, intentional) control representations. Through observational studies and task analyses, we have attempted to reveal the different conative structures in mobility [1,8,12].

Semantic similarity and semantic disruption

If the content of the interrupting task is apperceptually similar to that of the main task, disruption of the representations of the main task may occur. In a series of experiments, we observed that if semantic similarity is high, representations of the main task are more vulnerable to intrusions from prior experience, and blendings between the tasks emerge when their contents are confusingly similar. [3]

2 Memory and re-orientation

Encoding speed in the main task and interruption tolerance

Encoding speed, a construct grounded on the theory of long-term working memory (LTWM), denotes the time taken for the contents of short-term WM to be encoded to LTWM in a *robust and interruption-tolerant* manner. We proposed a model of six interaction-related constituents of encoding speed. In a set of experiments, we showed that after LTWM encoding, memory is safeguarded from interruptions, regardless of the intensity, complexity, or pacing of the interrupting task. However, when encoding resources were withdrawn, an interruption cost emerged, indicating that skilled encoding has to be supported. [4]

Attentive style in the main task and task resumption

To understand the role of attentive style in the main task, we conducted an experiment in which subjects performed either a link search or a content search on web pages, and their memory of the surface features (color, location, orthography) and of the semantic content (meaning) of the page elements were tested. As predicted by the *levels-of-processing principle*, memory of page elements depended on the orienting task, whereas task-*ir*relevant features of the elements were poorly remembered even when they were processed. A model of memory and attention in the resumption of browsing was advanced. [7]

Expectations vs. memory in guiding re-orientation

Expectations guide perceptual organization and selective processes of attention when switching back to the interrupted task. We investigated if users use explicit memory of a particular web page layout, or rely instead on expectations in re-orientation. Analysis of eye movements upon task resumption revealed that, despite the presence of memory traces as measured by a free recall test, expectations were utilized instead of explicit memory, most likely because accessing explicit memory requires effort and is slow, while task resumption with a web page needs to be quick. Our analysis suggests that expectations are formed through implicit learning (unconscious association formation), are rapidly evoked and executed, are relatively resistant to change, and often operate at a coarse level where the target (e.g., the link being searched for on a web page) is represented not as a discrete individual but as a member of a cluster or agglomeration (e.g., link panel). Re-orientation relying on explicit memory might contribute to anxiety and stress. [2]

THE SKILLED MEMORY APPROACH TO UI DESIGN

The next goal of our research will be to systematize our findings on the basis of LTWM theory. The motivation behind theory construction is to inform the design of non-disruptive UIs—UIs that minimize interruption costs (see [5]). Our distinctive approach has been to look at *UI support for memory skills* that enable users to manage interruptions [4,6], instead of building agents that block or schedule interruptions proactively.

The multitasking control approach involves giving consideration to the resources UIs provide for task control. Our practical work encompasses designing 1) a desktop feature for supporting the management of location-based messaging tasks while mobile [10], 2) non-disruptive presence cues to support calling decisions through an augmented Series-60 contact book [9], and 3) tactile feedback for long response times in mobile browsing [11].

We have identified basic principles for facilitating interruption tolerance, such as consistency, predictability, transparency, user control, short interaction chains, interruption lags, interruption locks, semantic access, and interactive reactivation [4]. Our results also suggest several design solutions for decreasing semantic confusion between tasks, most of which are related to supporting the contextual distinctiveness of memory traces, chunking episodes of the main task, timing interruptions between the chunks (or episodes), and the use of distinctive retrieval cues. [3]

Currently, we are constructing an experiment for identifying and comparing the reduction in interruption costs born by the proposed UI solutions in a single task domain.

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